# Bowen Ratio Surface Flux: Smith (FIFE)

## Summary:

The Bowen Ratio Surface Flux Observations (Smith) Data Set contains surface flux measurements made at selected sites within the FIFE area. The collection effort was conducted in 1987, 1988, and 1989 from sites equipped with Bowen ratio equipment operated by several different groups. Each surface flux station was capable of measuring the fluxes of net radiation, sensible heat, and latent heat using. The Bowen ratio stations measured the soil heat flux as well.

The surface flux and micrometeorological measurements available in this data set were collected from 2 locations within the FIFE study area. One of these sites was located at the bottom of a valley while the other was on the top of a ridge. During the IFC's data were collected daily.

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## 1. Data Set Overview:

### Data Set Identification:

Bowen Ratio Surface Flux: Smith (FIFE).
(Bowen Ratio Surface Flux Observations (Smith)).

## Data Set Introduction:

The Bowen Ratio Surface Flux Observations (Smith) Data Set contains surface flux measurements made at selected sites within the FIFE area during 1987, 1988, and 1989. Each surface flux station was capable of measuring the fluxes of net radiation, sensible heat, and latent heat using. The Bowen ratio stations measured the soil heat flux as well.

## Objective/Purpose:

The combined aim of the surface flux group was to use a network of ground based observing systems to measure fluxes of heat, water vapor and radiation at a number of points within the FIFE study area.

## Summary of Parameters:

Sensible heat flux, latent heat flux, surface soil heat flux, incoming solar radiation, incoming longwave radiation, outgoing solar radiation, outgoing longwave radiation, net radiation, mean horizontal wind speed, mean wind direction, mean vapor pressure, mean soil temperatures at 2, 8, 20 and 40 cm, soil moisture (at 5 and 20 cm depth), precipitation, mean air temperature, atmospheric pressure, surface albedo, Bowen ratio.

## Discussion:

Surface flux measurements were made at selected sites within the FIFE area. The major data collection effort was conducted in 1987 when 16 stationary sites were equipped with Bowen ratio equipment operated by several different groups. In 1988 and 1989, Bowen ratio surface flux stations were installed at 12 and 19 sites, respectively. Each surface flux station was capable of measuring the fluxes of net radiation, sensible heat, and latent heat using. The Bowen ratio stations measured the soil heat flux as well.

The surface flux and micrometeorological measurements available in this data set were collected from 2 locations within the FIFE study area. One of these sites (SITEGRID_ID = 1916) was located at the bottom of a valley while the other (SITEGRID_ID = 1478) was on the top of a ridge. Data were collected from both locations in 1987 during the four intensive field campaigns. In 1989, data were collected only at the ridge top site and only during IFC-5 in August. During the IFC's data were collected daily.

## Related Data Sets:

- Eddy Correlation Surface Flux Observation (USGS).
- Eddy Correlation Surface Flux Observation (UNL).
- Eddy Correlation Surface Flux Observation (GSFC).
- Eddy Correlation Surface Flux Observation (UK).
- Eddy Correlation Surface Flux Observation (Argonne).
- Bowen Ratio Surface Flux Observation (GSFC).
- Bowen Ratio Surface Flux Observation (KSU).

- Bowen Ratio Surface Flux Observation (Fritschen).
- Bowen Ratio Surface Flux Observation (UNL).
- Bowen Ratio Surface Flux Observation (USGS).

### FIS Data Base Table Name:

SURFACE_FLUX_30MIN_DATA.

# 2. Investigator(s):

### Investigator(s) Name and Title:

Dr. Eric A. Smith
Dept. of Meteorology, Florida State University

Dr. William L. Crosson
USRA/NASA

### Title of Investigation:

The retrieval of surface fluxes from a combination of satellite and surface platforms.

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### Requested Form of Acknowledgment.

The Bowen Ratio Surface Flux Observations (Smith) were collected and prepared by Drs. Eric Smith and William Crosson from Florida State University. Their contribution of these data is appreciated.

# 3. Theory of Measurements:

The components of the energy balance were determined with the Bowen Ratio Energy Balance (BREB) method. The BREB method is a combination of the transport and the energy balance equations. The Bowen ratio, **B** {a ratio of the gradient equations of sensible heat, **H** and latent heat, **E**} is given by:

**B = H / E. (1).**

where:

**H = -rho.c(p).K(h). dT/dz**

**E = -(rho.epsilon / P).l(v).K(v). de/dz**

where symbols are defined as:

**e** = Air vapor pressure
**epsilon** = Ratio of the molecular weights of water vapor and dry air
**c(p)** = Specific heat of air at constant pressure
**K(h)** = Eddy diffusivity for heat
**K(v)** = Eddy diffusivity for water vapor
**p** Atmospheric pressure
**rho** = Air density
**T** = Air temperature
**z** = Height or depth
**l(v)** = Latent heat of vaporization

Substituting (1) in the energy balance equation (2) yields the BREB (3). **Q** is net radiation and **G** is soil heat flux density.

**Q + G + H + E = 0 (2).**

In this system surface-air interface is considered as a closed system. Any energy flux coming in is considered positive and going out is negative.

**E = -(Q + G) / (1 + B) (3).**

# 4. Equipment:

## Sensor/Instrument Description:

- Net radiation sensor : Eppley PSP (upfacing & downfacing) and PIR (upfacing & downfacing)
- Method of calculating Rn: Averaged 10-s samples from four directional radiometers.
- Soil heat flux sensor: REBS HFT 1
- Upper layer heat storage sensor: Four-probe thermocouples in parallel.
- Method of calculating G2: Averaged 10-s samples from two dT/dt measurements.
- Method of calculating G1: Averaged 1-min samples from two plates.
- Heat capacity equation: **C(s) = rho(s) (0.785 + 4.18 RWC)**
- Bowen ratio sensor: CSI BR system with dual-bridge

- 25-um TCs and dew point hygrometer: (TCs are unaspirated and unshielded; hygrometer is a single cooled mirror instrument fed by regulated pumps through mixing chambers).
- Lower arm height: 10 cm (measured above canopy)
- Lower-upper arm separation: 1.25 m
- Pressure: parameter in Measured psychrometric constant
- Temperature and vapor sampling: 2 second frequency
- Exchange frequency: 3 min
- Duty cycle for 30 minute averaging: 72% period

For more information on the instrumentation used to collect these data see Tanner et al. 1987 and Smith et al. 1992a.

The equipment is designed to retrieve all major components of the surface energy budget along with a large set of measured and derived parameters describing the dynamical, thermodynamical, hydrological, and radiative properties of the ground surface and atmospheric surface layer. A total of 96 individual parameters are monitored by the equipment. Some sensor redundancy has been incorporated into the design to allow for backup measurements in case of main sensor failure and to provide cross-checks of the energy budget fluxes.

The surface radiation and energy budget station contains five sub-system components:

1. Flux radiometers for solar, infrared, and net radiation flux monitoring;
2. Sub-surface soil temperature, moisture and heat flux sensors for soil heat flux, soil heat capacity, and soil thermal conductivity monitoring;
3. A vertical temperature/moisture gradient monitoring system incorporating fine wire thermocouples and a cooled mirror hygrometer for estimation of the Bowen ratio;
4. Anemometer, wind vane, barometer, thermistor, hygristor, and rain-gauge sensors for monitoring wind, state parameters, and precipitation;
5. Microprocessor controlled data logger and cassette recording sub-system for data acquisition and real-time processing.

The station is totally portable, weather resistant and self contained; it utilizes one 10 watt unregulated solar panel to recharge a six volt data logger battery pack and one 20 watt regulated solar panel to recharge a 12-volt marine battery used to supply power to the dew point hygrometer pump, flow regulators, and intake valve switches. The frame members and rigging are constructed from commercially available galvanized pipe and wire cable. The system can be deployed or removed by two people in approximately two hours. Total system weight is approximately 400 pounds. The system requires no external power supply, thus it can be deployed in any type of low-land or mountainous terrain. The cost of a complete system is approximately 25,000 dollars.

**Collection Environment:**

Ground-based.

**Source/Platform:**

Ground.

**Source/Platform Mission Objectives:**

To measure surface radiation and energy budget components as well as meteorological variables, and to use these measurements to test and validate a biosphere/remote sensing model tailored for application to a grassland ecosystem.

**Key Variables:**

Sensible heat flux, latent heat flux, soil heat flux, incoming solar radiation, incoming longwave radiation, outgoing solar radiation, outgoing longwave radiation, net radiation, mean horizontal wind speed, mean wind direction, mean vapor pressure, mean soil temperature at 2, 8, 20, and 40 cm, precipitation, mean air temperature, atmospheric pressure, and Bowen ratio.

**Principles of Operation:**

Net radiation is obtained by measuring upward and downward solar and infrared fluxes at 1.75 meters above the surface with matched pairs of pyranometers and pyrgeometers and then differencing the separate directional fluxes. An additional pair of filtered pyranometers is included to provide a means to obtain a flux-based NDVI parameter. The pyranometers are temperature compensated Eppley PIR's using Suprasil-W inner domes to block IR wavelengths at (approximately) 3.0 um. The filtered pyranometers utilize Schott colored glass outer domes to provide short wave interference filtering at one of five selected spectral cutoffs (.395, .495, .610, .695, .780 um). The pyrgeometers are Eppley PIR's using polished silicon domes to reflect solar wavelengths below (approximately) 3.0 um; the pyrgeometer thermopiles are also temperature compensated. Each pyrgeometer thermopile is equipped with pairs of embedded thermistors for monitoring sink and dome temperatures; these are used to correct for heat diffusion losses or gains to the thermopile arising from thermal gradients within the radiometer body itself. These thermistor measurements are also used to provide a cross-check on the other temperature sensors at night when the radiometer bodies are in equilibrium with the atmosphere.

Soil heat flux is obtained by calculating storage in the upper 5-cm ground layer via a heat capacity calculation and then summing this term with the measured ground flux at a 5-cm depth. Two heat flux plates wired in parallel are used to obtain the 5-cm level Soil heat flux. The heat capacity calculation utilizes average layer temperatures obtained from two sets of 4-leg parallel thermocouple probes evenly distributed in the upper 5-cm layer. In addition, there are four independent soil thermistors nominally placed at 2, 8, 20, and 40 cm depths along with two gypsum soil moisture blocks nominally placed at 5 and 20 cm depths to provide for independent checks of heat capacity and thermal conductivity. The heat capacity coefficients used in the storage calculations are provided by the host hydrological monitoring group (the Kansas State Univ. Evapotranspiration Laboratory) based on bulk soil density and volumetric water content measurements.

The Bowen ratio system consists of two sensor arms, each 1.5 meters in length, which are suspended over the vegetation canopy. The lower arm is situated 10 cm above the top of the

canopy; the upper arm is situated 1.25 meters above the lower arm thus defining the height interval over which the temperature (T) and dew point temperature (Td) gradients are obtained. The average T and Td gradients are obtained every 3 minutes based on 2-second samples. The temperature sensors are unshielded 1-mil copper-constantan dual-bridge thermocouples. The dew point sensor is a General Eastern cooled mirror LED assembly which is fed air on an alternating 3-minute schedule from intakes on the upper and lower arms through separate mixing chambers regulated for 6-minute time constants. The flow rate into the mixing chambers is nominally set at 400 cc/min.

An anemometer/wind vane assembly is situated at 3.5 meters above the surface; an independent thermistor/hygristor sensor is situated 3.0 meters above the surface. A piezo-electric barometer unit is placed 1.0 meter above the surface. A one-millimeter resolution tipping rain-gauge is placed on the surface approximately 10 meters from the main station structure. The rain-gauge is NOT deployed with a wind screen.

The data acquisition and recording system is a Campbell Scientific CR-7 data logger programmed to retrieve energy budget fluxes every 30 minutes, 24 hours per day. With the exception of the Bowen ratio sensors which employ 2-second sampling, and the barometer sensor which employs 6-minute sampling, all additional sensors are sampled at 0.1 Hz. The data logger software is prepared under a program language editor operating on a portable battery operated Zenith PC computer implemented with MS-DOS. Thus data logger software can be quickly altered in the field and downloaded to the program memory through a simple RS-232 interface. By the same token, the portable computer can be used to retrieve sequences of the half hour data record residing in the CR-7's 40K data memory, back through the RS-232 port. A spreadsheet software package is then used on the PC to construct graphical renditions of data time series at the site for near-real time station monitoring. The principal data recording system is a standard cassette recorder; one cassette can hold up to two months of half hourly data before it needs replacements.

**Sensor/Instrument Measurement Geometry:**

See the *Principles of Operation Section*.

**Manufacturer of Sensor/Instrument:**

Fine-wire thermocouples:

Campbell Scientific
P. O. Box 551
Logan, UT 84321.

Cooled mirror hygrometer:

General Eastern Inst. Co.
Watertown, MA.

Soil and air thermistors:

Fenwal Electronics
Milford, MA.

Soil heat transducer:

Radiation & Energy Balance Systems, Inc. (REBS)
P.O. Box 15512
Seattle, WA 98115-0512.

Soil moisture blocks:

Delmhorst
Boonton, NJ.

Pyranometers:

Eppley Laboratories
Newport, RI.

Pyrgeometers:

Eppley Laboratories
Newport, RI.

Cup anemometer/vane:

Met One, Inc.
Grants Pass, OR.

Hygristor:

Phys-Chemical Research Corp.
NYC, NY.

Piezo-electric barometer:

Weather Measure
Sacramento, CA.

Tipping bucket raingauge:

High Sierra Electronics
Grass Valley, CA.

Data logging system:

Campbell Scientific
P.O. Box 551
Logan, UT 84321.

### Calibration:

Cooled mirror hygrometer: Factory calibrated prior to 1987 field campaign by Campbell Scientific using procedures recommended by General Eastern. During the experiment, the optical bias for mirror reflectance was adjusted every few days to its nominal value.

Pyranometers and pyrgeometers: Factory calibrated by Eppley Labs prior to 1987 and 1989 field campaigns. A radiometer intercomparison was performed during each of the campaigns to remove residual biases between radiometers. Net radiometer intercomparisons involving each of the investigators within the surface flux group were conducted in both 1987 and 1989. The FSU directional radiometers were set up as part of these intercomparisons. Adjustments have been made by the investigators to eliminate bias in net radiation measurements (See Field et al. 1992).

Soil heat transducers: Factory calibrated by REBS; inter-calibrated prior to 1987 field campaign.

Piezo-electric barometers: Calibrated against an AIR model HB-1A digital barometer.

#### Specifications:

Not available at this revision.

##### Tolerance:

Not available at this revision.

#### Frequency of Calibration:

See the *Calibration Section*.

#### Other Calibration Information:

None.

## 5. Data Acquisition Methods:

The data were acquired by the sensors; the system is designed to retrieve all major components of the surface energy budget along with a large set of measured and derived parameters describing the dynamical, thermodynamical, hydrological, and radiative properties of the ground surface and atmosphere surface layer. For details, see Smith et al. 1992a.

# 6. Observations:

## Data Notes:

Not available.

## Field Notes:

Not available at this revision.

# 7. Data Description:

## Spatial Characteristics:

The FIFE study area, with areal extent of 15 km by 15 km, is located south of the Tuttle Reservoir and Kansas River, and about 10 km from Manhattan, Kansas, USA. The northwest corner of the area has UTM coordinates of 4,334,000 Northing and 705,000 Easting in UTM Zone 14.

### Spatial Coverage:

These data were collected from 2 locations within the FIFE study area. In 1987, two sites, 2 and 38 were operated and in 1989 one site, 938, was operated. Site 38 and 938 were in the same location.

The exact location of each site is listed below:

| SITEGRID_ID | STN_ID | LATITUDE | LONGITUDE | NORTHING | EASTING | SLOPE | ELEVATION | ASPECT |
|---|---|---|---|---|---|---|---|---|
| | | | | | | Deg | Feet | |
| 1916-BRS | 2 | 39 05 56 | -96 35 30 | 4330296 | 708270 | 340 | | |
| 1478-BRS | 38 | 39 06 15 | -96 26 56 | 4331216 | 720603 | 350 | | |
| 1478-BRS | 938 | 39 06 15 | -96 26 53 | 4331223 | 720664 | 2 | 375 | N |

### Spatial Coverage Map:

Not available.

### Spatial Resolution:

These are point data except that the Bowen ratio flux instruments effectively sample fluxes from an area about 100 miles upwind of the sensors.

**Projection:**

Not available.

**Grid Description:**

Not available.

## Temporal Characteristics:

**Temporal Coverage:**

Surface flux data for the data described here were collected from May 27, 1987 to October 15, 1987 and on 20 days from July 21 to August 13, 1989.

**Temporal Coverage Map:**

Not available.

**Temporal Resolution:**

The data values represent 30-minute mean values; sampling is performed at 2 second intervals for Bowen ratio sensors and 10 seconds for all other sensors, with the exception of atmospheric pressure, which is sampled every 6 minutes.

Measurements are daily during each of the 5 IFC's, May 27 - June 7, June 25 - July 12, August 6 - August 22 and October 5 - October 17 in 1987, and July 22 - August 13 in 1989.

## Data Characteristics:

The SQL table definition for this data table is found in the SF_30MIN.TDF file located on FIFE CD-ROM Volume 1. The following chart lists only those variables that are contained in the data set described in this document.

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**Parameter/Variable Name**

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**Parameter/Variable Description** **Range** **Units** **Source**

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SITEGRID_ID
This is a FIS grid location code.
Site grid codes (SSEE-III) give
the south (SS) and the east (EE)

cell number in a 100 x 100 array
of 200 m square cells. The last
3 characters (III) are an instrument
identifier.

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STATION_ID
The station ID designating the
location of the observations.

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OBS_DATE
The date of the observations,
in the format (DD-mmm-YY).

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OBS_TIME
The time that the observation [GMT]
was taken, in GMT. The format
is HHMM.

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LATENT_HEAT_FLUX
The latent heat flux, the flux [Watts]
of the energy due to the evaporation [meter^-2]
of water.

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NET_RADTN
The net radiation, including both [Watts]
downward and upward energy. [meter^-2]

---

SENSIBLE_HEAT_FLUX
The sensible heat flux, the flux [Watts]
of the energy due to temperature [meter^-2]
differences.

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SOIL_HEAT_FLUX
The surface soil heat flux, the [Watts]
flux of energy into the soil. [meter^-2]

---

SOLAR_RADTN_DOWN
The downward (incoming) solar [Watts]
radiation. [meter^-2]

---

SOLAR_RADTN_UP
The upward (outgoing) solar [Watts]
radiation. [meter^-2]

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SOLAR_RADTN_NET
The net solar radiation. [Watts]
[meter^-2]

| | |
|---|---|
| SOLAR_RADTN_DOWN_SDEV<br>The standard deviation of SOLAR_RADTN_DOWN. | [Watts]<br>[meter^-2] |
| SOLAR_RADTN_UP_SDEV<br>The standard deviation of SOLAR_RADTN_UP. | [Watts]<br>[meter^-2] |
| SURF_ALBEDO<br>The surface short wave albedo. | [percent] |
| LONGWAVE_RADTN_DOWN<br>The downward (incoming) long wave radiation. | [Watts]<br>[meter^-2] |
| LONGWAVE_RADTN_UP<br>The upward (outgoing) long wave radiation. | [Watts]<br>[meter^-2] |
| LONGWAVE_RADTN_NET<br>The net long wave radiation (LONGWAVE_RADTN_DOWN + LONGWAVE_RADTN_UP). | [Watts]<br>[meter^-2] |
| BB_TEMP_LONGWAVE_DOWN<br>The black body temperature for LONGWAVE_RADTN_DOWN. | [degrees Kelvin] |
| BB_TEMP_LONGWAVE_UP<br>The black body temperature for LONGWAVE_RADTN_UP. | [degrees Kelvin] |
| SOIL_HEAT_FLUX_0_TO_5CM<br>The soil heat flux recorded somewhere between 0 and 5 cm in depth. Recorded at 5 cm. | [Watts]<br>[meter^-2] |
| HEAT_STORAGE<br>The heat storage in the top soil layer. | [Watts]<br>[meter^-2] |
| SOIL_WATER_POTNTL_0_TO_5CM<br>The soil water potential recorded somewhere between 0 and 5 cm in depth [bars]. This | [bars] |

| | |
|---|---|
| is the pressure required to extract water from the soil. Recorded at 5 cm. | |
| SOIL_WATER_POTNTL_5_TO_20CM<br>The soil water potential recorded somewhere between 5 and 20 cm in depth [bars]. This is the pressure required to extract water from the soil. Recorded at 20 cm. | [bars] |
| SOIL_TEMP_0_TO_25MM<br>The soil temperature recorded somewhere between 0 and 25 mm in depth. Recorded at 20 mm. | [degrees Celsius] |
| SOIL_TEMP_5_TO_10CM<br>The soil temperature recorded somewhere between 5 and 10 cm in depth. Recorded at 8 cm. | [degrees Celsius] |
| SOIL_TEMP_10_TO_20CM<br>The soil temperature recorded somewhere between 10 and 20 cm in depth. Recorded at 20 cm. | [degrees Celsius] |
| SOIL_TEMP_20_TO_50CM<br>The soil temperature recorded somewhere between 20 and 50 cm in depth. Recorded at 40 cm. | [degrees Celsius] |
| RAINFALL<br>The amount of rainfall in this 30 minutes. | [mm] |
| BOWEN_RATIO<br>The Bowen Ratio, the ratio of the SENSIBLE_HEAT_FLUX to the LATENT_HEAT_FLUX. | |
| WIND_SPEED<br>The average wind speed in this 30 minutes. | [meters]<br>[sec^-1] |
| WIND_DIR<br>The average wind direction in this 30 minutes. | [degrees from North] |

| | |
|---|---|
| WIND_SPEED_MIN<br>The minimum wind speed in this 30 minutes. | [meters]<br>[sec^-1] |
| WIND_SPEED_MAX<br>The maximum wind speed in this 30 minutes. | [meters]<br>[sec^-1] |
| WIND_DIR_MIN<br>The minimum wind direction in this 30 minutes. | [degrees from North] |
| WIND_DIR_MAX<br>The maximum wind direction in this 30 minutes. | [degrees from North] |
| WIND_DIR_SDEV<br>The standard deviation of the wind direction. | [degrees] |
| WIND_SPEED_HOR_MEAN<br>The mean horizontal wind speed in this 30 minutes. | [meters]<br>[sec^-1] |
| WIND_SPEED_LAT_MEAN<br>The mean lateral wind speed in this 30 minutes. | [meters]<br>[sec^-1] |
| AIR_TEMP_HIGH<br>The air temperature at the higher level. This is the higher of the movable sensor arms. | [degrees Celsius] |
| AIR_TEMP_OTHER<br>The air temperature at the other level. | [degrees Celsius] |
| AIR_TEMP_OTHER_SDEV<br>The standard deviation of air temperature at other level. | [degrees Celsius] |
| DELTA_TEMP<br>The difference in air temperature between the higher and lower level (AIR_TEMP_HIGH - AIR_TEMP_LOW). | [degrees Celsius] |

| | |
|---|---|
| VAPOR_PRESS_HIGH<br>The vapor pressure at the higher level. This is the higher of the movable sensor arms. | [kiloPascals] |
| DELTA_VAPOR_PRESS<br>The difference in the vapor pressure between the higher and lower level (VAPOR_PRESS_HIGH - VAPOR_PRESS_LOW). | [kiloPascals] |
| REL_HUMID_SDEV<br>The standard deviation of relative humidity. | [percent] |
| SURF_AIR_PRESS<br>The surface air pressure. | [kiloPascals] |
| FIFE_DATA_CRTFCN_CODE<br>The FIFE Certification Code for * the data, in the format: CGR (Certified by Group), CPI (Certified by PI), CPI-??? (CPI - questionable data), CPI-ELH (CPI - estimated latent heat, fluxes are model output). | |
| LAST_REVISION_DATE<br>in the format (DD-MMM-YY). | |

Footnotes:

* Valid levels

The primary certification codes are:

EXM Example or Test data (not for release) PRE Preliminary (unchecked, use at your own risk) CPI Checked by Principal Investigator (reviewed for quality) CGR Checked by a group and reconciled (data comparisons and cross checks)

The certification code modifiers are:

PRE-NFP Preliminary - Not for publication, at the request of investigator. CPI-MRG PAMS data that is "merged" from two separate receiving stations to eliminate transmission errors. CPI-??? Investigator thinks data item may be questionable.

** There are several missing value indicators in each column. The values may be positive or negative 9.9, 9.99, 99.99, 999, 999.99, 9999, 99999.99.

## Sample Data Record:

The following sample record contains all the fields in the surface flux record but only those fields that are described here (i.e., reported by E.A. Smith) contain data.

| SITEGRID_ID | STATION_ID | OBS_DATE | OBS_TIME | LATENT_HEAT_FLUX |
|---|---|---|---|---|
| 1478-BRS | 938 | 28-JUL-89 | 1215 | -7 |
| 1478-BRS | 938 | 28-JUL-89 | 1245 | -33.86 |
| 1478-BRS | 938 | 28-JUL-89 | 1315 | -58.86 |
| 1478-BRS | 938 | 28-JUL-89 | 1345 | -71.56 |

| NET_RADTN | SENSIBLE_HEAT_FLUX | SOIL_HEAT_FLUX | DIFFUSE_SOLAR_RADTN_DOWN |
|---|---|---|---|
| -6.32 | 8 | 5.59 | |
| 52.59 | -11.17 | -7.55 | |
| 124.1 | -40.26 | -24.93 | |
| 194.8 | -77.86 | -45.4 | |

| SOLAR_RADTN_DOWN | SOLAR_RADTN_UP | SOLAR_RADTN_NET | SOLAR_RADTN_DOWN_SDEV |
|---|---|---|---|
| 93 | 28 | 66 | 23 |
| 180 | 46 | 134 | 27 |
| 281 | 62 | 219 | 30 |
| 378 | 75 | 303 | 27 |

| SOLAR_RADTN_UP_SDEV | PAR_DOWN | PAR_UP | SURF_ALBEDO |
|---|---|---|---|
| 6 | | .297 | |
| 5 | | .257 | |
| 4 | | .221 | |
| 4 | | .198 | |

| LONGWAVE_RADTN_DOWN | LONGWAVE_RADTN_UP | LONGWAVE_RADTN_NET |
|---|---|---|
| 380 | 452 | -72 |
| 382 | 463 | -82 |
| 383 | 478 | -95 |
| 384 | 492 | -109 |

| BB_TEMP_LONGWAVE_DOWN | BB_TEMP_LONGWAVE_UP | TOTAL_RADTN_DOWN |
|---|---|---|
| 286 | 299 | |
| 287 | 301 | |
| 287 | 303 | |
| 287 | 305 | |

| TOTAL_RADTN_UP | SOIL_HEAT_FLUX_0_TO_5CM | SOIL_HEAT_FLUX_5_TO_10CM |
|---|---|---|
| 16.38 | | |
| 8.86 | | |
| 1.2 | | |
| 14.99 | | |

| SOIL_HEAT_FLUX_10_TO_20CM | HEAT_STORAGE | SOIL_WATER_POTNTL_0_TO_5CM |
|---|---|---|
| 2 | .426 | |
| 12 | .429 | |
| 23 | .431 | |

36 .433

| SOIL_WATER_POTNTL_5_TO_20CM | SURF_RADIANT_TEMP | SURF_RADIANT_TEMP_SDEV |
|---|---|---|
| 13.43 | | |
| 13.4 | | |
| 13.35 | | |
| 13.35 | | |

| SOIL_TEMP_0_TO_25MM | SOIL_TEMP_25MM_TO_5CM | SOIL_TEMP_5_TO_10CM |
|---|---|---|
| 24.08 | 25.63 | |
| 24.21 | 25.61 | |
| 24.57 | 25.56 | |
| 25.4 | 25.57 | |

| SOIL_TEMP_10_TO_20CM | SOIL_TEMP_20_TO_50CM | RAINFALL | BOWEN_RATIO |
|---|---|---|---|
| 25.59 | 24.69 | 0 | .485 |
| 25.6 | 24.79 | 0 | .33 |
| 25.55 | 24.82 | 0 | .684 |
| 25.5 | 24.84 | 0 | 1.088 |

| WIND_SPEED | WIND_DIR | WIND_SPEED_MIN | WIND_SPEED_MAX | WIND_SPEED_SDEV |
|---|---|---|---|---|
| 3.66 | 207.4 | 2.681 | 4.836 | |
| 3.648 | 212.3 | 2.442 | 4.996 | |
| 2.906 | 217.3 | 1.963 | 4.277 | |
| 2.842 | 209.5 | 1.804 | 3.799 | |

| WIND_DIR_SDEV | TIME_WIND_SPEED_MIN | TIME_WIND_SPEED_MAX |
|---|---|---|
| 9.68 | | |
| 11.06 | | |
| 10.64 | | |
| 11.96 | | |

| TIME_WIND_DIR_MIN | TIME_WIND_DIR_MAX | WIND_SPEED_HOR_MEAN |
|---|---|---|
| 1.684 | | |
| 1.949 | | |
| 1.761 | | |
| 1.399 | | |

| WIND_SPEED_LAT_MEAN | WIND_SPEED_VERT_MEAN | WIND_SPEED_HOR_SDEV |
|---|---|---|
| 3.249 | | |
| 3.084 | | |
| 2.312 | | |
| 2.474 | | |

| WIND_SPEED_LAT_SDEV | WIND_SPEED_VERT_SDEV | AIR_TEMP_LOW | AIR_TEMP_HIGH |
|---|---|---|---|
| 23.94 | | | |
| 25.14 | | | |
| 26.41 | | | |
| 27.45 | | | |

| AIR_TEMP_OTHER | AIR_TEMP_MEAN | AIR_TEMP_MEAN_SDEV | AIR_TEMP_OTHER_SDEV |
|---|---|---|---|
| 23.11 | | | .246 |
| 24.24 | | | .337 |
| 25.48 | | | .473 |
| 26.7 | | | .331 |

| DELTA_TEMP | WET_BULB_TEMP_LOW | WET_BULB_TEMP_HIGH | VAPOR_PRESS_LOW |
|---|---|---|---|

```
-.041
.074
.245
.466
  VAPOR_PRESS_HIGH    VAPOR_PRESS_MEAN   VAPOR_PRESS_SDEV   REL_HUMID_LOW
-------------------   ----------------   ----------------   -------------
2.284
2.336
2.39
2.416
REL_HUMID_HIGH   REL_HUMID_SDEV   SURF_AIR_PRESS   FRICTION_VELOC
--------------   --------------   --------------   --------------
.304              97.2
.676              97.2
1.048              97.2
.972              97.2
W_T_MEAN    W_E_MEAN    CO2_CONTENT   OZONE_CONTENT   CO2_CONTENT_SDEV
----------  ----------  -----------   -------------   ----------------
OZONE_CONTENT_SDEV    CO2_FLUX    OZONE_FLUX   FIFE_DATA_CRTFCN_CODE
------------------   ----------   ----------   ---------------------
CPI-ELH
CPI
CPI
CPI
LAST_REVISION_DATE
------------------
10-FEB-92
10-FEB-92
10-FEB-92
10-FEB-92
```

# 8. Data Organization:

## Data Granularity:

These are point data except that the Bowen ratio flux instruments effectively sample fluxes from an area about 100 miles upwind of the sensors. Surface flux data for the data described here were collected from May 27, 1987 to October 15, 1987 and on 20 days from July 21 to August 13, 1989.

A general description of data granularity as it applies to the IMS appears in the EOSDIS Glossary.

## Data Format:

The CD-ROM file format consists of numerical and character fields of varying length separated by commas. The character fields are enclosed with a single apostrophe. There are no spaces between the fields. Each file begins with five header records. Header records contain the following information:

Record 1 Name of this file, its table name, number of records in this file, and principal investigator name.

Record 2 Path and filename of the previous data set, and path and filename of the next data set. (Path and filenames for files that contain another set of data taken at the same site on the same day.)

Record 3 Path and filename of the previous site, and path and filename of the next site. (Path and filenames for files of the same data set taken on the same day for the previous and next sites, sequentially numbered by SITEGRID.)

Record 4 Path and filename of the previous date, and path and filename of the next date. (Path and filenames for files of the same data set taken at the same site for the previous and next date.)

Record 5 Column names for the data within the file, delimited by commas.

Record 6 Data records begin.

Each field represents one of the attributes listed in the chart in the *Data Characteristics Section* and described in detail in the TDF file. These fields are in the same order as in the chart.

# 9. Data Manipulations:

## Formulae:

### Derivation Techniques and Algorithms:

There are many derived variables; see Smith et al. 1992a for details.

## Data Processing Sequence:

### Processing Steps:

See Smith et al. 1992a.

### Processing Changes:

None.

## Calculations:

### Special Corrections/Adjustments:

Nighttime visible and near-infrared fluxes have been set to 0. For inter-IFC periods and some other periods when the Bowen ratio system was not operational, latent and sensible heat fluxes have been estimated using the Businger-Dyer flux profile functions.

**Calculated Variables:**

See Smith et al. 1992a.

### Graphs and Plots:

None.

## 10. Errors:

### Sources of Error:

Not available at this revision.

### Quality Assessment:

It was recognized early in the study that standardization's of "constant" (e.g., physical constants of the air, psychrometric constant, etc.), methods of computation, integration and reporting time, etc. were necessary. These were agreed upon in planning sessions. Preliminary data sets were compared among stations and instruments from different manufacturers for estimating net radiation, soil heat flux, water vapor density, temperature, solar radiation, and wind speed, it was necessary to have confidence that differences in observations were due to site differences and not due to instrumentation. Short periods of missing or bad data have been estimated by interpolation. Longer periods of missing energy fluxes have been estimated using the Businger-Dyer flux profile functions.

**Data Validation by Source:**

The Hydrological Science Branch at NASA Goddard Space Flight Center was given the responsibility to compare flux data from all flux stations. This served two purposes: 1) as a data quality check, and 2) a preliminary analysis of site differences. Surface flux measurements from the various investigators have been compared in a paper by Smith et al. 1992b.

**Confidence Level/Accuracy Judgment:**

The following are the best estimates of accuracy for a single flux estimate:

- Net radiation +/- 4 to 7%
- Soil heat flux +/- 30%
- Latent heat flux +/- 15 to 20 % or +/-30 W m^-2, whichever is larger
- Sensible heat flux +/- 15 to 20 % or +/-30 W m^-2, whichever is larger

None of these estimates addresses the variability of flux estimates from site-to-site.

**Measurement Error for Parameters:**

Not available at this revision.

**Additional Quality Assessments:**

Several of the key surface flux parameters have undergone extensive intercomparisons and examination for spikes in the data. The data have also been checked for an imbalance in the energy equation. Details of these analyses are described in the Surface Flux Baseline 1992 document on FIFE CD-ROM Volume 1.

FIS staff applied a general QA procedure to some of the fields in the data set to identify inconsistencies and problems for potential users. As a general procedure, the FIS QA consisted of examining the maximum, minimum, average, and standard deviation for numerical field. Inconsistencies and problems found in the QA check are described in the *Known Problems with the Data Section*.

**Data Verification by Data Center:**

The data verification performed by the ORNL DAAC deals with the quality of the data format, media, and readability. The ORNL DAAC does not make an assessment of the quality of the data itself except during the course of performing other QA procedures as described below.

The FIFE data were transferred to the ORNL DAAC via CD-ROM. These CD-ROMs are distributed by the ORNL DAAC unmodified as a set or in individual volumes, as requested. In addition, the DAAC has incorporated each of the 98 FIFE tabular datasets from the CD-ROMs into its online data holdings. Incorporation of these data involved the following steps:

- Copying the entire FIFE Volume 1, maintaining the directory structure on the CD-ROM.
- Using data files, documentation, and SQL code provided on the CD-ROM to create a database in Statistical Analysis System (SAS).
- Creating transfer files to transfer the SAS metadata database to Sybase tables.

Each distinct type of data (i.e. "data set" on the CD-ROM), is accompanied by a documentation file (i.e., .doc file) and a data format/structure definition file (i.e., .tdf file). The data format files on the CD-ROM are Oracle SQL commands (e.g., "create table") that can be used to set up a relational database table structure. This file provides column/variable names, character/numeric type, length, and format, and labels/comments. These SQL commands were converted to SAS code and were used to create SAS data sets and subsequently to input data files directly from the CD-ROM into a SAS dataset. During this process, file names and directory paths were captured and metadata was extracted to the extent possible electronically. No files were found to be corrupted or unreadable during the conversion process.

Additional Quality Assurance procedures were performed as follows:

- Statistical operations were performed to calculate minimum and maximum values for all numeric fields and to create a listing of all values of the character fields. During this process, it was determined that various conventions were used to represent missing values. (Note: no modifications were made to any data by the DAAC). In most cases, missing value identification conventions were discussed in the accompanying .doc file. Based on a visual check of the minimum and maximum values, no glaring errors or holes were identified that might indicate errors introduced during CD-ROM mastering by the FIFE project or data ingest by the DAAC.
- Some minor inconsistencies and typographical errors were identified in some of the character fields and column labels, however, no modifications were made to the data by the DAAC.
- Some conversions of ASCII data were necessary to move the data from a DOS platform to a UNIX platform. Standard operating system conversion utilities were used (e.g., dos2unix).
- Much of the metadata required for archival is imbedded in the narrative documentation accompanying the data sets and extracted manually by DAAC staff who have read the .doc files provided on the CD-ROM and have hand entered this information into the metadata database maintained by the DAAC. QA procedures have been performed on these metadata to identify and eliminate typographical errors and inconsistencies in naming conventions, to ensure that all required metadata is present, and to ensure the accuracy of file names and paths for retrieval.
- Data requested for distribution to users are checked to verify that files copied from disk to other media remain uncorrupted.

As errors are discovered in the online tabular data by investigators, users, or DAAC staff, corrections are made in cooperation with the principal investigators. These corrections are then distributed to users. CD-ROM data are corrected when re-mastering occurs for replenishment of CD-ROM stock.

# 11. Notes:

## Limitations of the Data:

Not available.

## Known Problems with the Data:

Different missing values are used within each column. These may be positive or negative 9.9, 9.99, 99.99, 999.99, 9999, or 99999.99.

Nighttime fluxes are noisy, especially under neutral conditions.

The missing value indicators in the following fields can have been inadvertently converted to 1000. Use these data with caution.

| Name | Name |
|---|---|

```
------------------------   -------------------
DIFFUSE_SOLAR_RADTN_DOWN   TOTAL_RADTN_DOWN
SOLAR_RADTN_DOWN           TOTAL_RADTN_UP
SOLAR_RADTN_UP             HEAT_STORAGE
SOLAR_RADTN_NET            RAINFALL
SOLAR_RADTN_DOWN_SDEV      WIND_DIR_MIN
SOLAR_RADTN_UP_SDEV        WIND_DIR_MAX
LONGWAVE_RADTN_DOWN        CO2_CONTENT
LONGWAVE_RADTN_UP          O3_CONTENT
LONGWAVE_RADTN_NET         CO2_STDEV
BB_TEMP_LONGWAVE_DOWN      O3_STDEV
BB_TEMP_LONGWAVE_UP
```

### Usage Guidance:

Not available at this revision.

### Any Other Relevant Information about the Study:

None.

# 12. Application of the Data Set:

Not available.

# 13. Future Modifications and Plans:

The FIFE field campaigns were held in 1987 and 1989 and there are no plans for new data collection. Field work continues near the FIFE site at the Long-Term Ecological Research (LTER) Network Konza research site (i.e., LTER continues to monitor the site). The FIFE investigators are continuing to analyze and model the data from the field campaigns to produce new data products.

# 14. Software:

Software to access the data set is available on the all volumes of the FIFE CD-ROM set. For a detailed description of the available software see the *Software Description Document*.

# 15. Data Access:

### Contact Information:

ORNL DAAC User Services
Oak Ridge National Laboratory

Telephone: (865) 241-3952
FAX: (865) 574-4665

Email: ornldaac@ornl.gov

### Data Center Identification:

ORNL Distributed Active Archive Center
Oak Ridge National Laboratory
USA

Telephone: (865) 241-3952
FAX: (865) 574-4665

Email: ornldaac@ornl.gov

### Procedures for Obtaining Data:

Users may place requests by telephone, electronic mail, or FAX. Data is also available via the World Wide Web at http://daac.ornl.gov.

### Data Center Status/Plans:

FIFE data are available from the ORNL DAAC. Please contact the ORNL DAAC User Services Office for the most current information about these data.

## 16. Output Products and Availability:

Bowen Ratio Surface Flux Observations (Smith) data are available on FIFE CD-ROM Volume 1. The CD-ROM filename is as follows:

\DATA\SUR_FLUX\30_MIN\GRIDxxxx\YyyMmm\ydddgrid.BRS or
\DATA\SUR_FLUX\30_MIN\GRIDxxxx\Yyyyy\ydddgrid.BRS

Where *xxxx* is the four digit code for the location within the FIFE site grid, *yy* is the last two digits of the year (e.g., Y87 = 1987), *yyyy* is the four digits of the century and year (e.g., Y1987 - 1987), *mm* is the month of the year (e.g., M12 = December), and *ddd* is the day of the year, (e.g., 061 = sixty-first day in the year). Note: capital letters indicate fixed values that appear on the CD-ROM exactly as shown here, lower-case indicates characters (values) that change for each path and file.

The format used for the filenames is: *ydddgrid.sfx*, where *grid* is the four-number code for the location within the FIFE site grid, *y* is the last digit of the year (e.g., 7 = 1987, and 9 = 1989), and *ddd* is the day of the year. The filename extension (*.sfx*), identifies the data set content for the file (see the *Data Characteristics Section*) and is equal to .BRS for this data set.

# 17. References:

## Satellite/Instrument/Data Processing Documentation.

Tanner, B.D., J.P. Greene, and G.E. Bingham. 1987. A Bowen ratio design for long-term measurements. Am. Soc. of Agric. Eng. St. Joseph Mich, ASAE Tech. Pap. 87-2503.

## Journal Articles and Study Reports.

Field, R.T., L.J. Fritschen, E.T. Kanemasu, E.A. Smith, J.B. Stewart, S.B. Verma and W.P. Kustas. 1992. Calibration, comparison and correction of net radiometer instruments used during FIFE. J. Geophys. Res. 97(D17):18,681-18,695.

Fritschen, L.J., and J.R. Simpson. 1989. Surface energy and radiation balance systems: General description and improvements. J. Appl. Meteorol. 28:680-689.

Fritschen, L.J; P. Qian, E.T. Kanemasu, D. Nie, E.A. Smith, J.B. Stewart, S.B. Verma and M.L. Wesely. 1992. Comparison of surface flux measurement systems used in FIFE 1989. J. Geophys. Res. 97(D17):18,697-18,713.

Nie, D., and E.T. Kanemasu. 1989. Comparison of net radiation on slopes. In: Proc. 19th Conf. Agric. and Forest Meteorol. Charleston, SC, Am. Meteor. Soc., Boston, MA.

Nie, D., E.T. Kanemasu, L.J. Fritschen, H.L. Weaver, E.A. Smith, S.B. Verma, R.T. Field, W.P. Kustas, and J.B. Stewart. 1992. An intercomparison of surface energy flux measurement systems used during FIFE 1987. J. Geophys. Res. 97(D17):18,715-18,724.

Smith, E.A., W.L. Crosson, and D. Tanner. 1992a. Estimation of surface heat and moisture fluxes over a prairie grassland. 1. In situ energy budget measurements incorporating a cooled mirror dew point hygrometer. J. Geophys. Res. 97(D17):18,557-18,582.

Smith, E.A., A.Y. Hsu, W.L. Crosson, R.T. Field, L.J. Fritschen, R.J. Gurney, E.T. Kanemasu, W.P. Kustas, D. Nie, W.J. Shuttleworth, J.B. Stewart, S.B. Verma, H.L. Weaver, and M.L. Wesely. 1992b. Area-averaged surface fluxes and their time-space variability over the FIFE experimental domain. J. Geophys. Res. 97(D17):18,599-18,622.

Tanner, C.B. 1960. Energy balance approach to evapotranspiration from crops. Soil Sci. Soc. Amer. Proc. 24:1-9.

Verma, S.B. 1990. Micrometeorological methods for measuring surface fluxes of mass and energy. Remote Sensing Reviews. 5:99-115.

Wesely, M.L., D.H. Lenschow, and O.T. Denmead. 1989. Flux measurement techniques. In: Global Tropospheric Chemistry-Chemical Fluxes in the Global Atmosphere. pp. 31-46. National Center for Atmospheric Research, Boulder, CO. 107 pp.

### Archive/DBMS Usage Documentation.

Contact the EOS Distributed Active Archive Center (DAAC) at Oak Ridge National Laboratory (ORNL), Oak Ridge, Tennessee (see the *Data Center Identification Section*). Documentation about using the archive and/or online access to the data at the ORNL DAAC is not available at this revision.

## 18. Glossary of Terms:

A general glossary for the DAAC is located at Glossary.

## 19. List of Acronyms:

AMS Automatic Meteorological Station BPI Byte per inch BREB Bowen Ratio Energy Balance CCT Computer Compatible Tape DAAC Distributive Active Archive Center EOSDIS Earth Observing System Data and Information System FIS FIFE Information System FSU Florida State University HFT Heat Flux Thermometer IFOV Instantaneous Field of View LAI Leaf area index Mbps Megabyte per second ORNL Oak Ridge National Laboratory PAMS Portable Automatic Mesonet PIR Epply Precision Infrared Radiometer PSP Precision Spectral Pyranometer REBS Radiation and Energy Balance Systems SAMS Super AMS TC Thermocouple URL Uniform Resource Locator

A general list of acronyms for the DAAC is available at Acronyms.

## 20. Document Information:

April 28, 1994 (citation revised on October 15, 2002).

This document has been reviewed by the FIFE Information Scientist to eliminate technical and editorial inaccuracies. Previous versions of this document have been reviewed by the Principal Investigator, the person who transmitted the data to FIS, FIS staff member, or a FIFE scientist generally familiar with the data. It is believed that the document accurately describes the data as collected and as archived on the FIFE CD-ROM series.

### Document Review Date:

October 15, 1996.

### Document ID:

ORNL-FIFE_SF30_BRS.

### Citation:

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## Document Curator:

DAAC Staff

## Document URL:

http://daac.ornl.gov